International Efforts In Nanotube Standards

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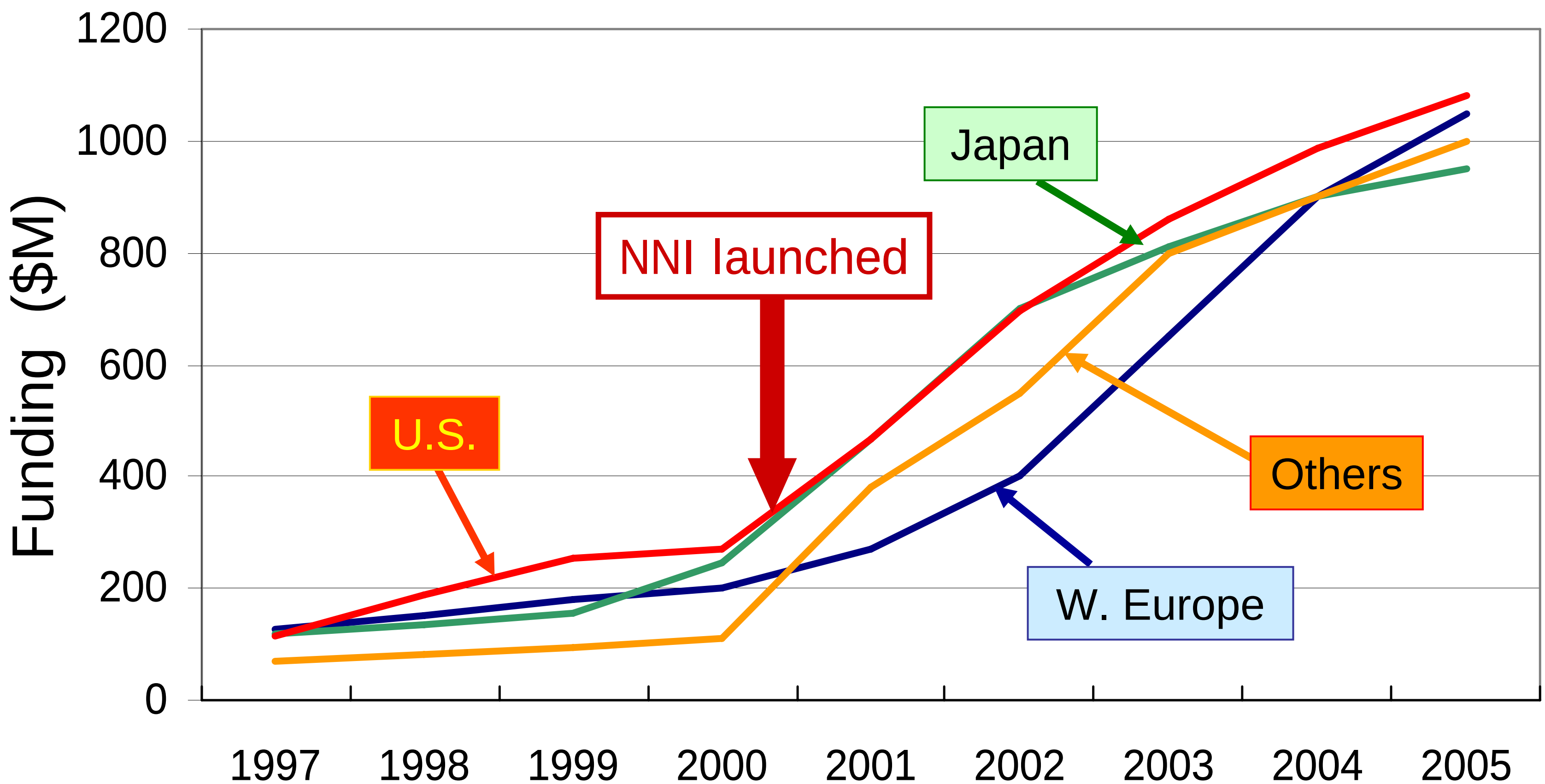
International Nanotech R&D Funding

U.S. Estimate for: 2006 = $1.3 billion; 2007 = $1.4 billion; Request for 2008 = $1.45 billion	Total EU for FP7 = $1.7 billion to 2013 Germany for 2008 = $460 million Russia until 2012 = $1.4 billion/yr



Why Standards?

- Enable interoperability among products
- Provide test and measurement methods for describing, quantifying and evaluating product attributes such as material, processes and functions
- Provide a basis for more efficient transactions in the domestic and international marketplace
  - How do I make sure you are selling what I'm buying?
  - Technical/quality/environmental management
- Support commercialization and market development
  - Speeds diffusion of new technologies into commercialization e.g.,IEEE 802.11 b,g,h,n…
- Support appropriate legislation/regulation
- Foster innovation and competitiveness in emerging technology areas
- Identifying gaps in knowledge

Standards Important For Nanotech Development and Commercialization

- **Global competition in nanotechnology is intense**
  - Imperative for best of each nation's technology to be incorporated into internationally-developed specifications and standards
- **Innovation in nanotechnology dependent on standards based on solid science and engineering**
  - Standards not so founded can constrain innovation and entrench inferior technologies
  - Consensus specifications documents serve as highly informative and instructional information for advancing field
- **Standards are key to addressing the highly multi-disciplinary and broad based nature of nanotechnology—cross-sectorial standards typical**
  - Example: "Neuro-knitting" of CNS nerve cells—biochemistry, molecular biology, engineering, physics, chemistry, medicine
- **Process type standards likely will play important role**
  - Environmental, health, and safety standards are a high priority on agenda for responsible development of nanotechnology

International Standards Development Organizations

National Body International Standards Organizations

ISO

IEC

Treaty-Based International Standards Organizations

ITU

OECD

Standards Development Orgs. With Global Reach

IEEE

semi

ASTM INTERNATIONAL

Many Organizations Have Standards Efforts on Nanotechnology Underway

	ISO TC 229 Nanotech-nologies	IEC TC 113 Nanotech. Stand. For Electrical & Electronic Products & Systems	OECD WP Manufactured Nano-materials	ASTM E56 Nanotech-nology	IEEE Nanotech-nology Council Standards Committee
Chair	UK BSI Peter Hatto IonBond	U.S. Thomas Chapin Underwriters Laboratory	U.S. Jim Willis EPA	Vicki Colvin Rice Univ.	Daniel Gamota Motorola
Secretariat or Equivalent	UK BSI Jose Alcorta	Germany Norbert Fabricius Forschung. K. Gmbh	OECD	ASTM	IEEE
Administrator of U.S. TAG or Equivalent	ANSI Heather Benko	NEMA	U.S. EPA	ASTM	IEEE

Cooperation Among Stds. Dev. Orgs. Working in Nanotechnology

- MOUs being developed for ISO collaboration with IEC and OECD
- Joint Working Groups between ISO TC229 and IEC TC113 for WG1 and WG2
  - likely WG3 if IEC TC113 forms an EHS WG
  - Formal arrangements for operation of joint WGs still in drafting stage
- OECD WP on Mfg Nanomaterials has had representative at last two ISO TC229 Plenary meetings in Berlin (May 2007) and in Korea (December 2006) and has ongoing dialog with the ISO TC229 WG1 concerning a working definition for “manufactured nanomaterials”
- CEN has formal liaison status with ISO TC229
- ISO and IEEE have agreement for use of joint logos on ISO Standards developed on basis of major input from IEEE

ISO TC 229 - Nanotechnologies

- Chair – Dr. Peter Hatto, UK IonBond, Inc.
- Secretariat – Jose Alcorta, BSI
- Inaugural meeting in London on Nov. 9-11, 2005
- Subsequent meetings twice per year – May-June and November-December;
  - 2006 in Tokyo and Seoul;
  - 2007 in Berlin and Singapore;
  - 2008 in Paris and Tel Aviv
- Working group structure with three working groups
  - Terminology and nomenclature
  - Metrology and characterization
  - Environment, health, and safety
- Broad and active work program underway

Scope of ISO/TC 229 (*Approved 11/2005*)

Standardization in the field of nanotechnologies that includes **either or both** of the following:

- *Understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometers in one or more dimensions where the onset of size-dependent phenomena enables novel applications,*
- *Utilizing the properties of nanoscale materials that differ from the properties of individual atoms, molecules, and bulk matter, to create improved materials, devices, and systems that exploit these new properties*

Specific tasks include developing standards for: terminology and nomenclature; metrology and instrumentation, including - specifications of reference materials, test methodologies, modeling and simulation; and science-based health, safety, and environmental practices.

IEC TC 113: Nanotechnology Standardization for Electrical and Electronics Products and Systems

- Working Groups:
  - 1: Terminology and nomenclature (Joint Working Group with ISO/TC 229 WG 1)
  - 2: Measurement and characterization (Joint Working Group with ISO/TC 229 WG 2)
  - 3: Performance of nanomaterials for electrotechnical components and systems
- Meetings
  - Inaugural Plenary – March 26-28, 2007, Frankfurt Germany
  - December 4-7, 2007, Singapore (co-located meeting with ISO/TC 229)
- Scope
  - Standardization of the technologies relevant to electrical and electronic products and systems in the field of nanotechnology in close cooperation with other committees of IEC and ISO TC 229
- Program of Work
  - No current items under development

OECD Working Party on Manufactured Nanomaterials

- Established in 2006
- Program of work addresses human health and environmental safety issues associated with nanomaterials
- Work is currently undertaken through six projects
  - An OECD Database on Human Health and Environmental Safety Research
  - Human Health and Environmental Safety Research Strategies on Manufactured Nanomaterials
  - Safety Testing of a Representative Set of Nanomaterials
  - Manufactured Nanomaterials and Test Guidelines
  - Co-operation on Voluntary Schemes and Regulatory Programs
  - Co-operation on Risk assessment.

ASTM E 56 on Nanotechnology

- Chairman: Dr. Vicki Colvin Rice University
- Vice-Chairman: Dr. Akira Ono AIST
- Scope:
  - The development of standards and guidance for nanotechnology & nanomaterials,
  - The coordination of existing ASTM standardization related to nanotechnology needs. This coordination shall include the apportioning of specific requests for nanotechnolgoy standards through ASTM's existing committee base, as well as the maintenance of appropriate global liaison relationships with activities (internal and external) related to this subject area. The Committee shall participate in the development of symposia, workshops, and other related activities to enhance the development of standards.
- Seven Subcommittees operate under ASTM E 56
- Subcommittee E56.02 on Characterization: Physical, Chemical, and Toxicological Properties
  - WK9952 Standard Practice for Measuring Length and Thickness of Carbon Nanotubes Using Atomic Force Microscopy Methods
  - WK9953 Standard Practice for Measuring Diameter and Wall Thickness of Multi-wall Carbon Nanotubes (MWNT) Using Transmission Electron Microscopy Methods
- Other Subcommittees:
  - E56.01 Terminology and Nomenclature
  - E56.03 Environment, Health, and Safety
  - E56.04 International Law and Intellectual Property
  - E56.05 Liaison and International Cooperation
  - E56.90 Executive
  - E56.91 Strategic Planning and Review
- Published Standard E2456, *Terminology for Nanotechnology,* 12/2006

IEEE Nanotechnology Council

- Programme of Work
  - 1650: *Standard Test Methods for Measurement of Electrical Properties of Carbon Nanotubes*
    - *Approved as an American National Standard (ANS) - 2006*
  - 1690: *Standard Methods for the Characterization of Carbon Nanotubes Used as Additives in Bulk Materials*
- Nanoelectronics Standards Roadmap
  - Capture and categorize areas of interest for standards related to nanoelectronics
  - http://standards.ieee.org/getieee/nano/nanoelectronics_roadmap_v1.pdf

Membership of ISO/TC 229

National Bodies Represented on ISO/TC 229:

- Participating Countries - 27
  - *Australia, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, India, Iran, Israel, Italy, Japan, Korea, Malaysia, Netherlands, Poland, Russian Federation, Singapore, Spain, Sweden, Switzerland, Thailand, United Kingdom, United States*
- Observer Countries - 7
  - *Argentina, Egypt, Estonia, Hong Kong, Morocco, Slovakia, Venezuela*

Scopes of ISO TC229 WGs

Working Group 1: Terminology and Nomenclature

- Leadership assigned to Canada, Dr. Clive Willis, WG 1 Convenor
- Scope of WG 1:
  - Define and develop unambiguous and uniform terminology and nomenclature in the field of nanotechnologies to facilitate communication and to promote common understanding

Working Group 2: Measurement and Characterization

- Leadership assigned to Japan, Dr. Shingo Ichimura, WG 2 Convenor
- Scope of WG 2:
  - The development of standards for measurement, characterization, and test methods for nanotechnologies, taking into consideration needs for metrology and reference materials

Working Group 3: Health, Safety and Environment

- Leadership assigned to United States, Mr. Steve Brown of Intel Corporation is the WG 3 Convenor
- Scope of WG 3:
  - The development of science-based standards in the areas of health, safety, and environmental aspects of nanotechnologies

Membership of U.S. TAG to ISO/TC 22

Established June 2005

- ANSI serves as U.S. TAG Administrator for the ISO/TC 229
- 57+ TAG Members:
  - **Industry** – Cabot, Degussa, Dow Chemical, DuPont, GE, HP, Honeywell, Hyperion, Intel, Intertox, Motorola, NanoDynamics, Nanophase, NanoScale Materials, Siemens, TSI Incorporated, Veeco
  - **Government** – EPA, Dept. of Energy, Dept. of Defense, NASA, NIOSH, NIST, US Army, NNCO
  - **Academia** – Cornell, UC Berkeley, Marshall, Purdue, Rice, University of Tennessee, University of Florida, University of Texas A&M
  - **Standards Developing Organizations** – AAMI, AIHA, ACS, ASME, CAP, CTFA, IEEE, IEST, NSF, SEMI, UL, USP
  - **Legal Organizations and NGOs** – Bergeson and Campbell, Environmental Defense, Foresight Nanotech Institute, Keller & Heckman, King & Spalding, Pitney-Hardin

U.S. TAG to ISO/TC 229

- ISO TC/229 U.S. TAG WGs mirror ISO/TC 229 WG structure
  - TAG Working Groups are advisory to the U.S. TAG
  - U.S. TAG retains final decision making authority on all U.S. positions and ballots
- TAG Chair
  - Dr. Clayton Teague, NNCO
- TAG Working Group Chairs
  - Terminology and Nomenclature – Dr. Fred Klaessig, Degussa Corporation
  - Measurement and Characterization – Dr. Ray Tsui, Motorola
  - Health, Safety and Environment – Dr. Laurie Locascio, NIST and Mr. Chris Bell, Sidley Austin LLP

Current ISO TC 229 New Work Items

TC 229 WG-1
Convener: Canada
Terminology & Nomenclature

ISO 27687 – Terminology and Definition of Nanoparticles

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Five more
at next TC meeting

TC 229 WG-2
Convener: Japan
Metrology & Characterization

ISO Tech Specification SEM & EDXA in the Characterization of

NIR-Photoluminescence (NIR-PL) Spectroscopy

Raman Spectroscopy

Thermo Gravimetric Analysis in the Purification

Characterization of Multi-Walled Carbon Nanotubes

TC229 WG-3
Convener: U.S.
E H & S Aspects of Nanotechnologies

ISO TR "Health and Safety Practices in Occupational Settings Relevant to
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nanoparticles for inhalation toxicity testing

Guidance on physico-chemical characterization of engineered nanoscale materials for toxicologic assessment

All countries are being stretched to support this heavy workload with the necessary broad range of experts

Current Level 1 Matrix for SWCNTs (Part A)
Purity & Structural Properties, SWCNTs

Property / Category	SEM/EDX (Lead:USA)	TEM (Lead:USA, Co-lead:Japan)	Raman Spectroscopy (Lead:USA)	UV-Vis-NIR Absorption (Lead:Japan)	NIR-PL/ Fluorescence (Lead:Japan)	TGA (Lead:USA, Co-lead:Korea)	TG-MS (Lead:Japan)
	Method						
Morphology	Tube structure, bundle thickness, orientation	Wall structure, amorphous carbon, metal catalyst coatings					
Purity	Non-carbon impurities	Tube surface cleanliness	Nanotube and non-nanotube carbon	Carbonaceous content (Quantitative) (Lead: USA)		Non-carbon content (Quantitative) Non-CNT content (Quantitative)	Non-carbon content (Quantitative)
Length and Diameter	Length and diameter	Tube diameter, metal cluster size	Diameter (Lead: Japan)	Diameter (Lead: Japan)	Diameter		
Tube Type			Metallic/ Semiconducting	Metallic/ Semiconducting (Lead: USA, Co-lead: Korea)	Chirality (Semi conducting tubes)		
Dispersability/ Solubility	Tube bundling			Tub bundling or separation (solution)	Tube bundling		
Additional						Oxidation/transition temperatures	Oxidation/transition temperatures
Other Participants	China	China, Korea	Korea	Korea	USA	China	

TBD: Canada and Germany

Part B of Level 1 Matrix for SWCNTs

Level 1. Measuring Purity and Structural Properties of SWCNT Material

(Part B -- More Detailed Analysis)

Approximate Total: 25 mg

Sample Size	< 1 mg	< 1 mg	< 1 mg	< 1 mg	< 1 mg	10-20 mg
Property / Category	**Method**					
	Fluorescence Spectroscopy	**Surface Area Measurement**	**XPS**	**AFM**	**FTIR**	**Micro ICP**
Morphology						
Purity			Elemental composition (surface)			Elemental Composition (Quantitative)
Length and Diameter	Diameter			Length and diameter		
Tube Type	Chirality (Semi-conducting tubes)					
Dispersability/ Solubility	Tube bundling			Tube bundling		
Additional		Surface area and pore size	Chemical binding state of elements		Identify functional groups and volatile compounds	

Part C of Level 1 Matrix for SWCNTs

Level 1. Measuring Purity and Structural Properties of SWNT Material

(Part C -- Additional Analysis)

Approximate Total: 50 mg

Sample Size	<1mg	5-10 mg	5-10 mg	5-10 mg	<1mg	5-10 mg
Property / **Category**	**Method**					
	STM	**XRD**	**XRF**	**EXAFS**	**E-beam Diffraction**	**Light, X-ray and Neutron Scattering**
Morphology						
Purity			Elemental composition (Quantitative and non-destructive)			
Length and Diameter						Length to diameter ratio
Tube Type	Chirality (Metallic tubes)				Chirality (Metallic and semi-conducting)	
Dispersability/ Solubility						Tube bundling/aggregation
Additional		Crystallanity		Chemical binding state and neighboring atom information		

Key Messages

- **Nanotechnology is being commercialized rapidly in new materials and simple applications with resultant strong push for standards development**
- **Coordination and collaboration among all national, regional & international SDOs is CRITICAL for nanotech development**
  - **Urgent that this be achieved early**
  - **Avoid divergent approaches and duplicative standards**
  - **Ensure rational and effective use of limited resources**
- **Great opportunity to influence international standards**
  - **Early stage in technology but progress is rapid**
- **Support the SDOs! Enlist your best scientific and technical expertise to participate in national and international standards development processes**